Power-Hardware-in-the-Loop Test of VSC HVDC Connection for Offshore Wind Power Plants

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Publication date:
2012

Document Version
Publisher's PDF, also known as Version of record

Power-Hardware-in-the-Loop Test of VSC HVDC Connection for Offshore Wind Power Plants

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June 26, 2012
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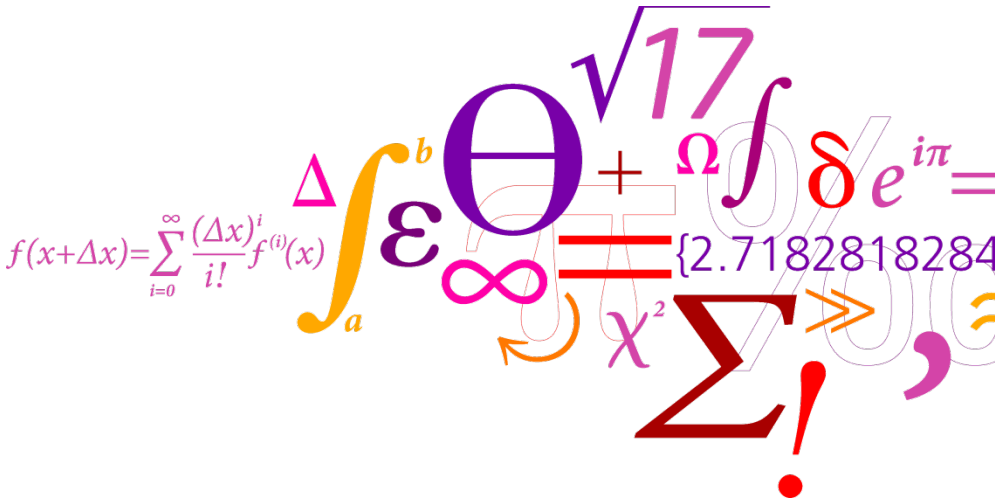
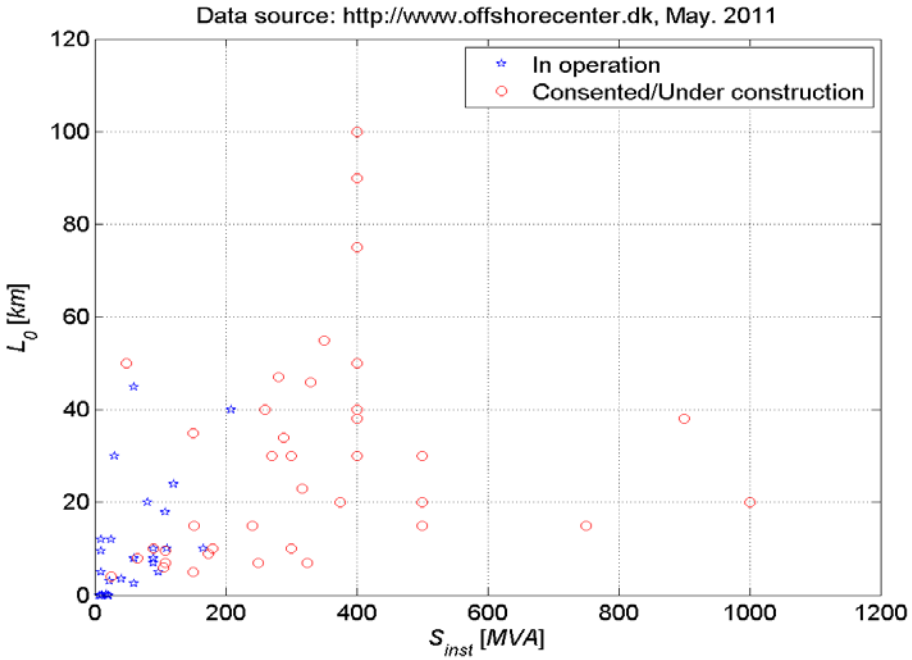


Outline

- Introduction
- HVDC Transmission System
- PHIL Platform
- Experiemt Results
- Conclusion
- Energy Storage Simulation Case

Introduction

- Many future WPPs will be commissioned as offshore
  - With longer transmission distances
  - Higher installed capacity



Power Transmission Options

- HVAC Vs. HVDC

Critical Issues

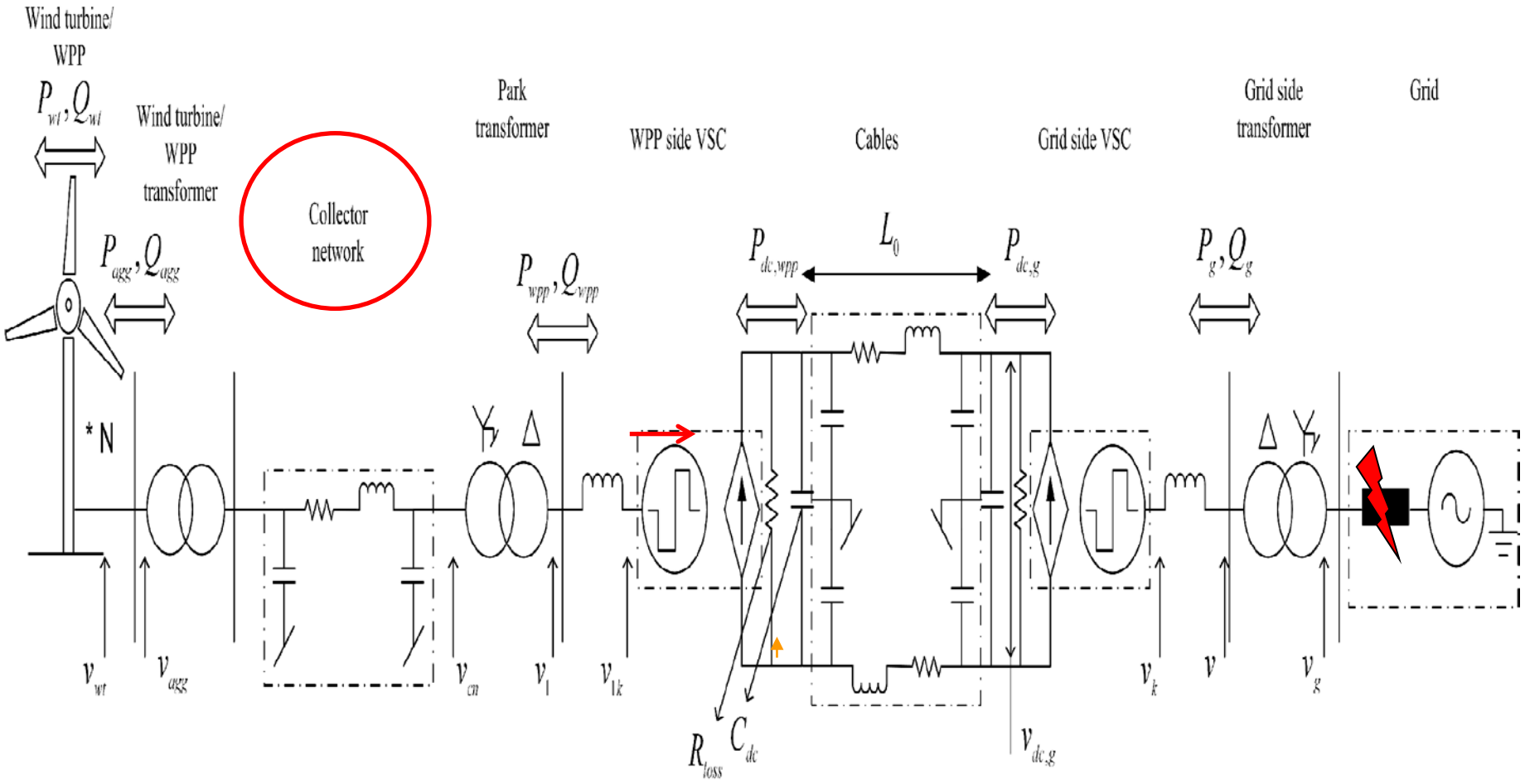
- Cost
- Energy Losses
- Resonance
- System services
- Conditions of the grid at the PCC
- Control options and requirements
- Some case specific issues, for e.g., environmental issues

- An off-shore wind power plant (WPP) interconnected to the on-shore grid via VSC-HVDC
- To verify the H/W interaction & the control co-ordination between the WPP and the VSC of the HVDC
- To provide a FRT response during the grid faults
- Technical challenges still remain

  : Detailed WPP representation with cables

  : Inclusion of both end VSCs

HVDC Transmission System



Electrical Structure of an Offshore WPP

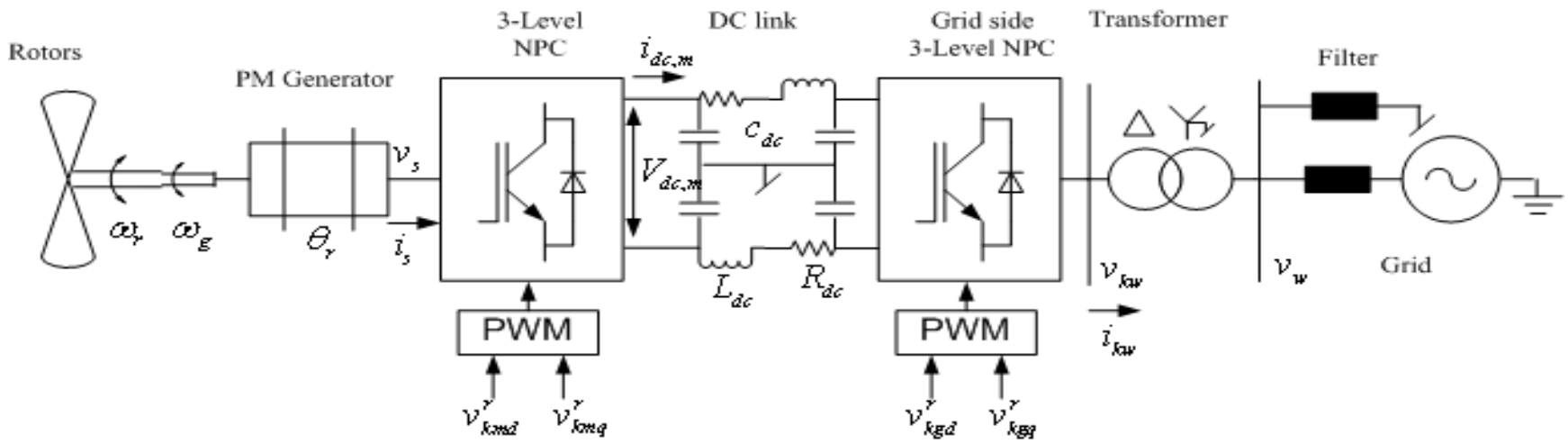
Real Time Simulation Platform

- RTDS is a power system simulator that solves electromagnetic transients in real time

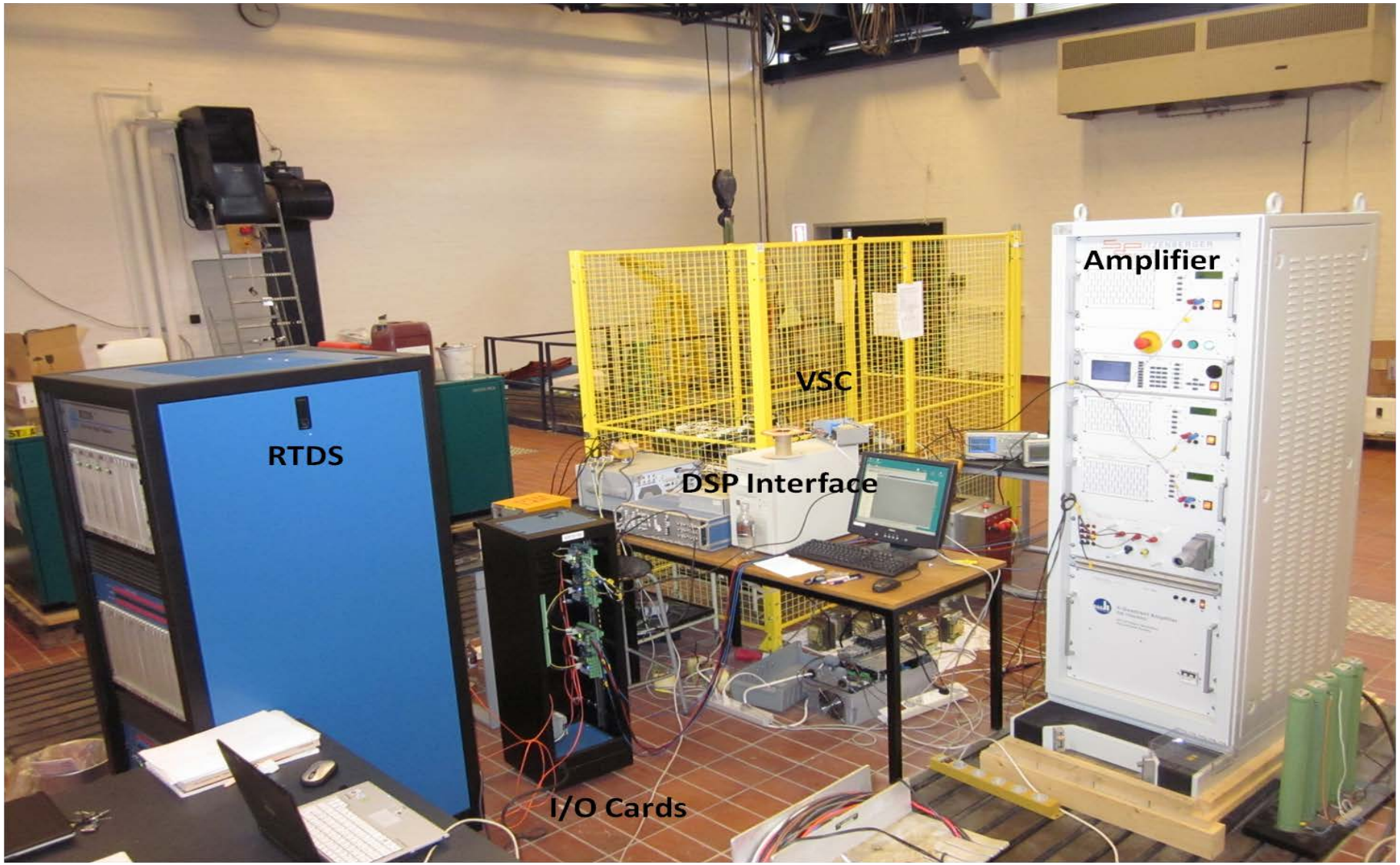
What is ***Real Time*** Simulation:

- By using the RTDS Simulator, a system's response over 1 second is computed in ***exactly*** 1 second.
- For a given time step of say 50 microseconds, all calculations required to determine the power system's state are solved in precisely that amount of time. → Sustain real time operation

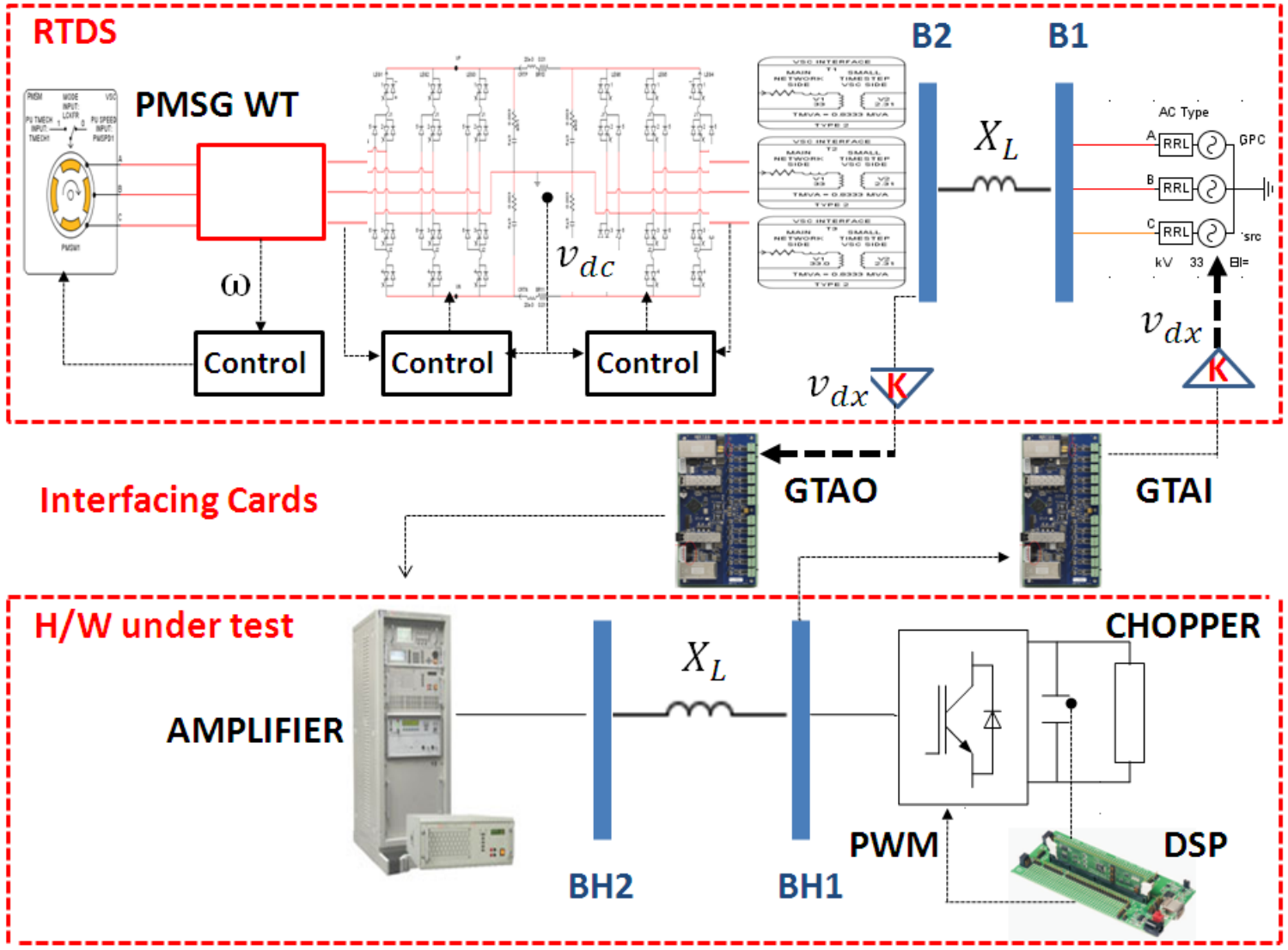
Wind Turbine Model



- Implemented in a Real time digital simulator (RTDS)
- Full converter based on permanent magnet generator
- No gear-box – direct drive type
- Power rating – 2 MW
- During the AC side voltage dip situation, the excess of wind power is dissipated into a DC chopper resistor


Amplifier
VSC
RTDS
DSP Interface
I/O Cards

Power-Hardware-In-the-Loop (PHIL) Test



Important aspects

- Startup – energize the HVDC link and the offshore grid
- Steady state operation
  - – active power transfer
  - – frequency and voltage control at PCC
- Fault handling
  - - Low Voltage Ride Through

Fault handling

Low voltage ride through

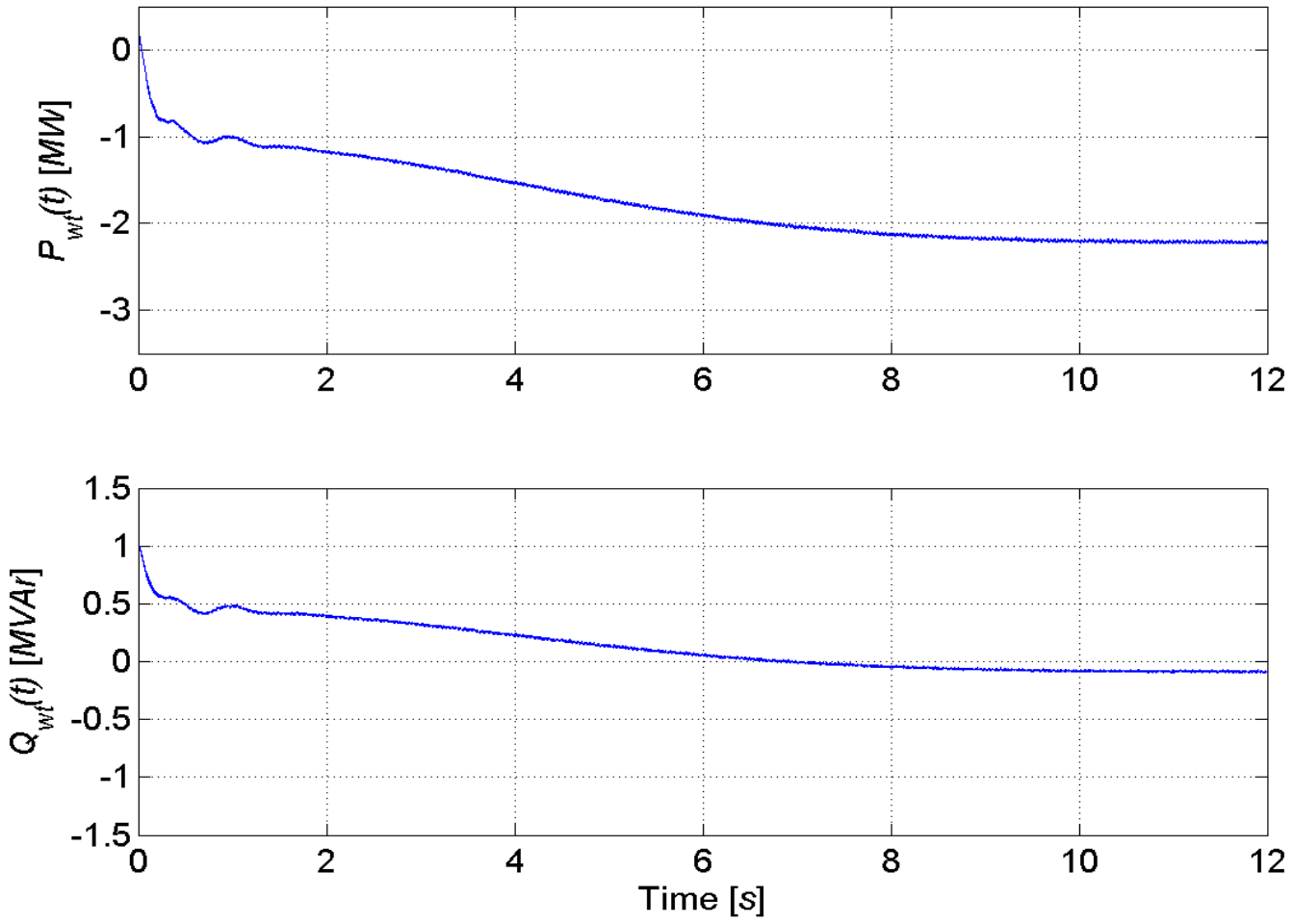
- Use chopper - simple and robust; the physical size of a DC chopper and the efforts to remove the heat is enormous
- AC voltage immitation technique may be used - most modern full-converter based wind turbines are already equipped with LV-FRT mode; do not have to seperate or distinguish between grid side faults and the collector network side faults

WPP Side VSC

- The main function of the WPP side VSC of the HVDC link is to provide synchronizing voltages to the wind turbines
- A DC voltage feedback control is implemented to ensure regulated AC voltage magnitude at the collector network
- When a fault occurs at the grid end (the HVDC voltage level exceeds beyond a threshold level), a FRT mode is activated
- During the FRT mode, the WPP side VSC is taken into DC voltage control mode which allows the collector network AC voltage to drop

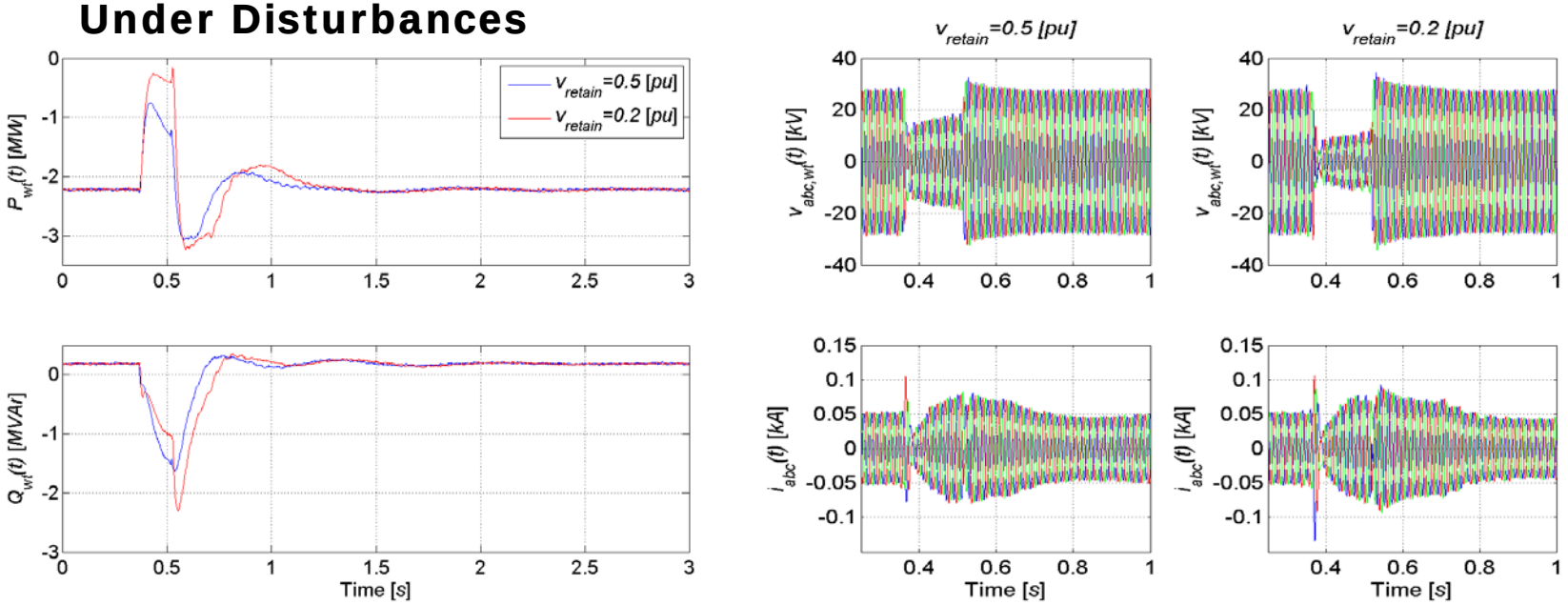
PHIL Experiment Results

Steady State Operation



PHIL Experiment Results (continue)

Under Disturbances



➔ During any disturbances at the grid side, the WPP side VSC is set to a FRT mode

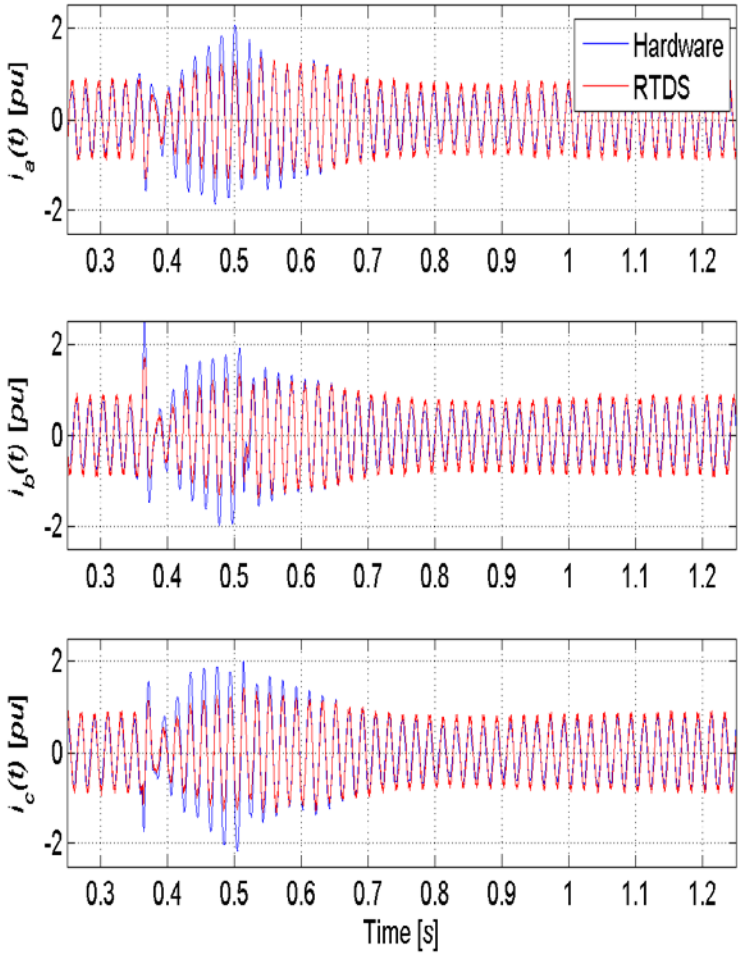
➔ AC voltage magnitude at the collector network is reduced accordingly

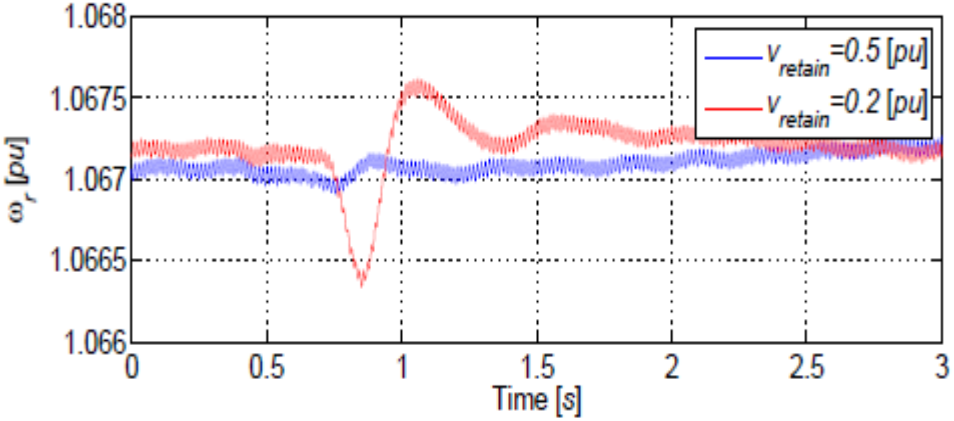
➔ Wind turbine responds by lowering the active power output

➔ Power balance is thus maintained in the system

PHIL Experiment Results (continue)

Under Disturbances





(a) Wind turbine generator speed

Conclusion

➔ This particular experiment contribute towards building in-depth knowledge on the steady-state and dynamic behavior of WPPs connected through VSC-HVDC links, and in order to provide recommendation for future developments.

➔ The results confirm a good co-ordination between the wind turbine and the WPP side VSC.

➔ The response from the wind turbine is very identical to the situation when it is connected to a strong AC super grid, as the WPP side VSC is able to provide a stable voltage regulation at the collector network.